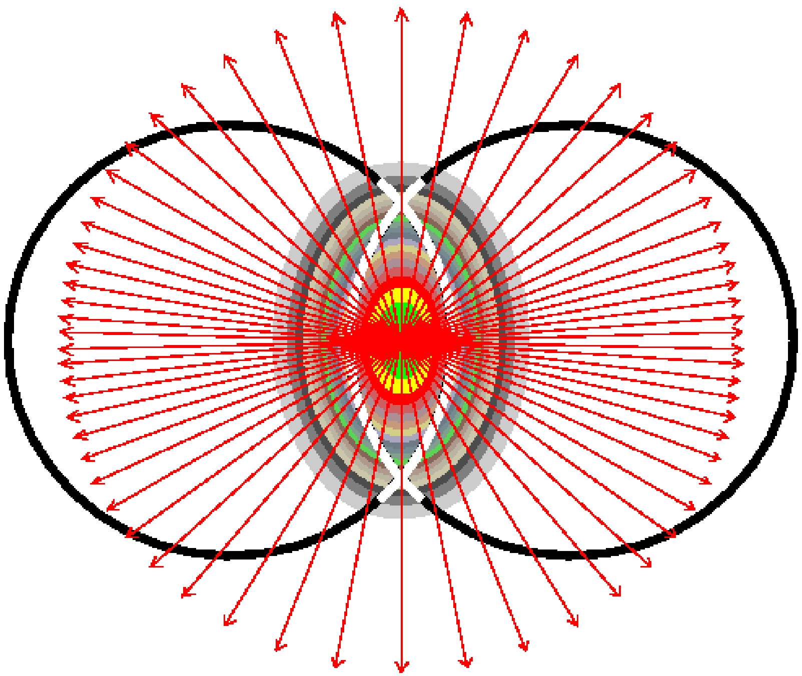
# Measurement of Jet Properties in p+p and Au+Au

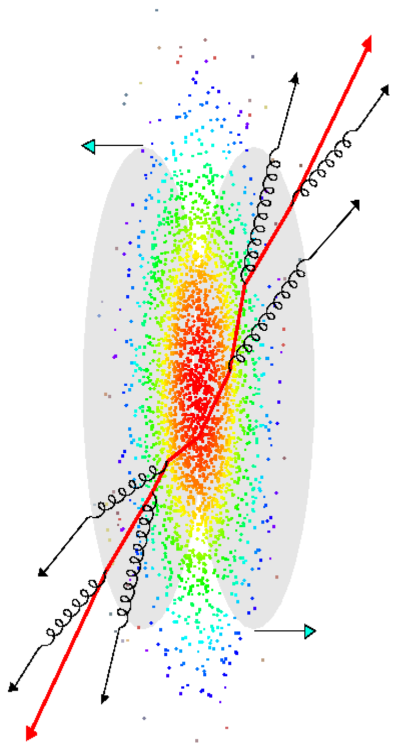



Jan Rak
for PHENIX

Department of Physics and Astronomy
IOWA STATE UNIVERSITY

# Hard scattering in Heavy Ion collisions

schematic view of jet production



Particle production @RHIC

—$dn_{ch}/d\eta\,|_{\eta=0} = 670$, $N_{total} \sim 7500$
92% of (15,000) all quarks
from vacuum !

Jets @RHIC:

—produced early $\tau<1$fm
—primarily from gluons
—30-50% of particle production

Observed via:

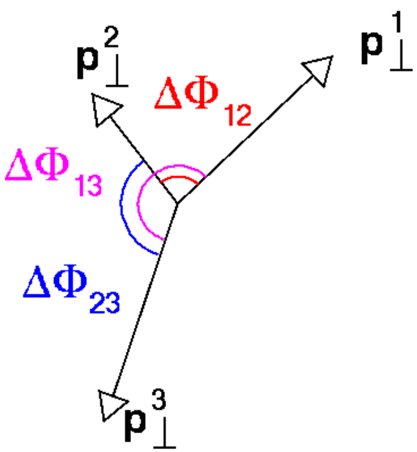
—fast leading particles
—azimuthal correlations

Scattered partons radiate energy in colored medium

→ suppression of high $p_t$ particles $R_{AA}$

→ modification of azimuthal correlation between jet fragments $\langle k_T \rangle$

# Two-Particles Correlation Function

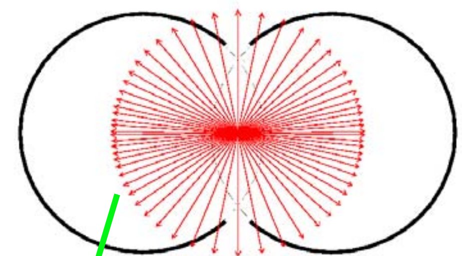


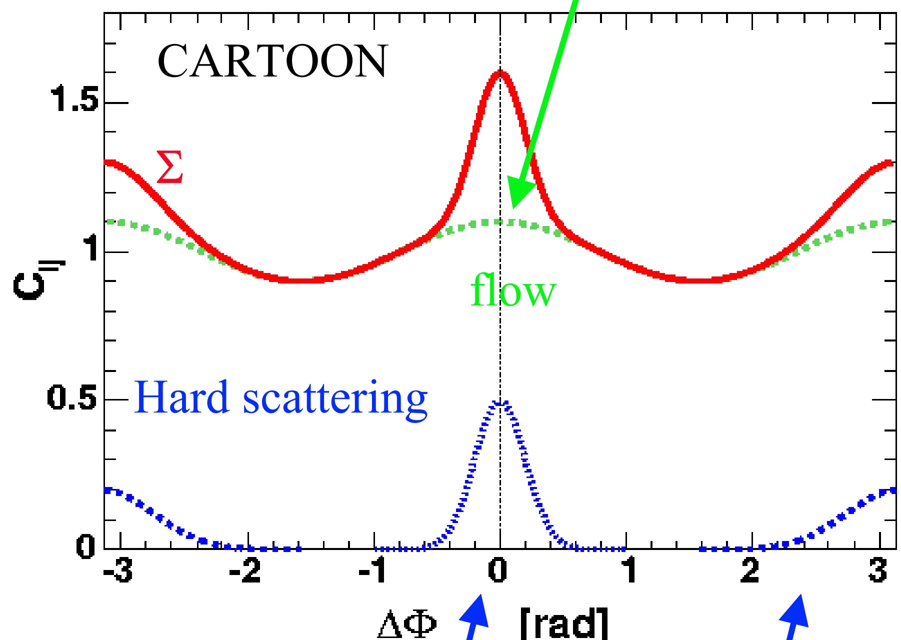

$$C_{ij}(\Delta\phi) = \frac{dN_{ij}}{d\Delta\phi_{ij}}$$

We observe a sum of

- Flow anisotropy (cos)
- Hard scattering peaks (gauss)

$C(\Delta\varphi) \propto \cos(2\Delta\varphi)$






$C(\Delta\varphi) \propto \mathrm{gauss}(\Delta\varphi=0)+\mathrm{gauss}(\Delta\varphi=\pi)$

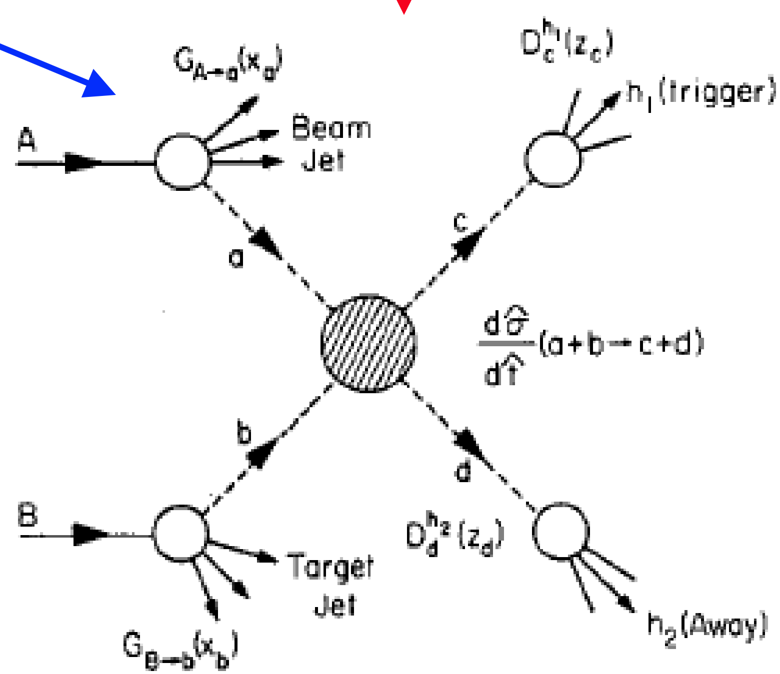
# pQCD collinear factorization

Production yield in hard-scattering regime factorizes

$$\sigma_{AB \to hX} \propto f_{a/A}(x_a, Q^2{}_a) \otimes f_{b/B}(x_b, Q^2{}_b) \otimes \sigma_{a\,b \to cd} \otimes D_{h/c}(z_c, Q^2{}_c)$$

Parton distribution function

Fragmentation function

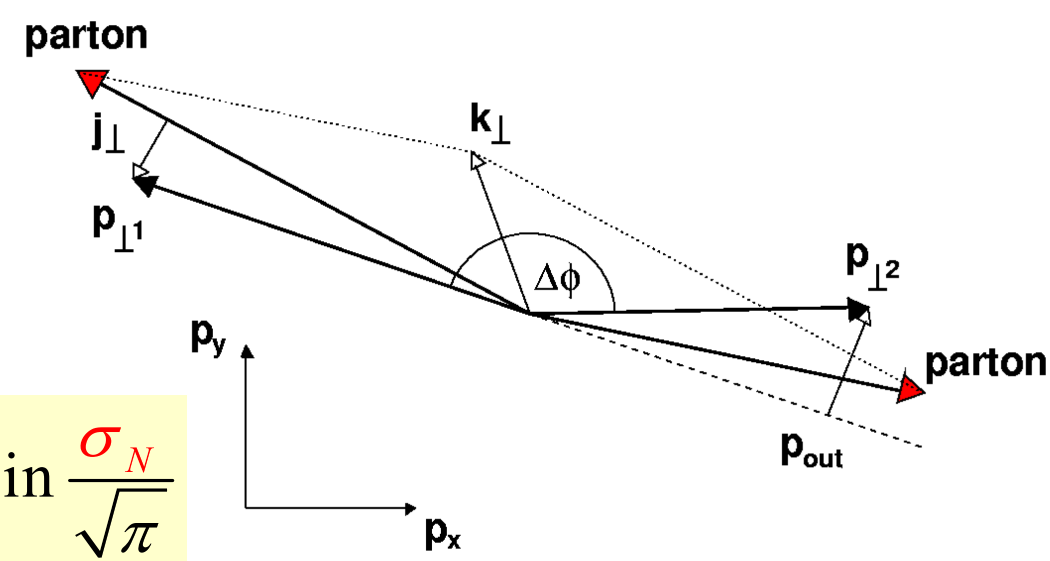



**$D_{h/c}(z_c, Q^2{}_c) \approx$ production probability of hadron $h$ (momentum fraction $z_c = p_{Th}/p_{Tc}$) from parton $c$**

# Jet Shape Parameters

$$\langle k_\perp^2 \rangle = \langle k_\perp^2 \rangle_{\text{vac}} + \langle k_\perp^2 \rangle_{\text{IS nucl}} + \langle k_\perp^2 \rangle_{\text{FS nucl}}$$

$\langle |k_{\perp y}| \rangle$ = the mean effective transverse momentum of the two colliding partons in the plane perp. to the beam axis.



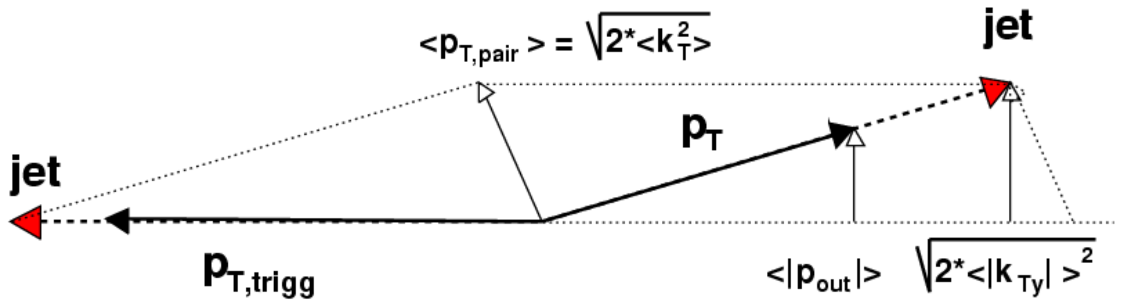

$\langle |j_{\perp y}| \rangle$ = the mean transverse momentum of the hadron with respect to the jet axis in the plane perpendicular to the beam axis.

$$\left\langle \left| j_{\perp y} \right| \right\rangle = \frac{1}{\sqrt{\pi}} \sqrt{\left\langle j_\perp^2 \right\rangle} = \left\langle p_\perp \right\rangle \sin \frac{\sigma_N}{\sqrt{\pi}}$$

$$\left\langle \left| k_{\perp y} \right| \right\rangle \ \left\langle z \right\rangle \approx \left\langle p_\perp \right\rangle \sqrt{\sigma_F^{\ 2} - \sigma_N^{\ 2}}$$

# Out of the plane momentum component

$p_{out}$ the component of momentum out of the plane formed by the beam and the trigger particle




In simplified case of collinear fragmentation – no jet frag. trans. mom. $\langle|j_{Ty}|\rangle=0$

$$\boxed{\langle|p_{out}|\rangle^2 = 2\,\langle|k_{Ty}|\rangle^2 \langle z\rangle^2 \langle x_h\rangle^2 \approx \langle p_T\rangle^2 \sin(\sqrt{2/\pi}\,\sigma_F)}$$

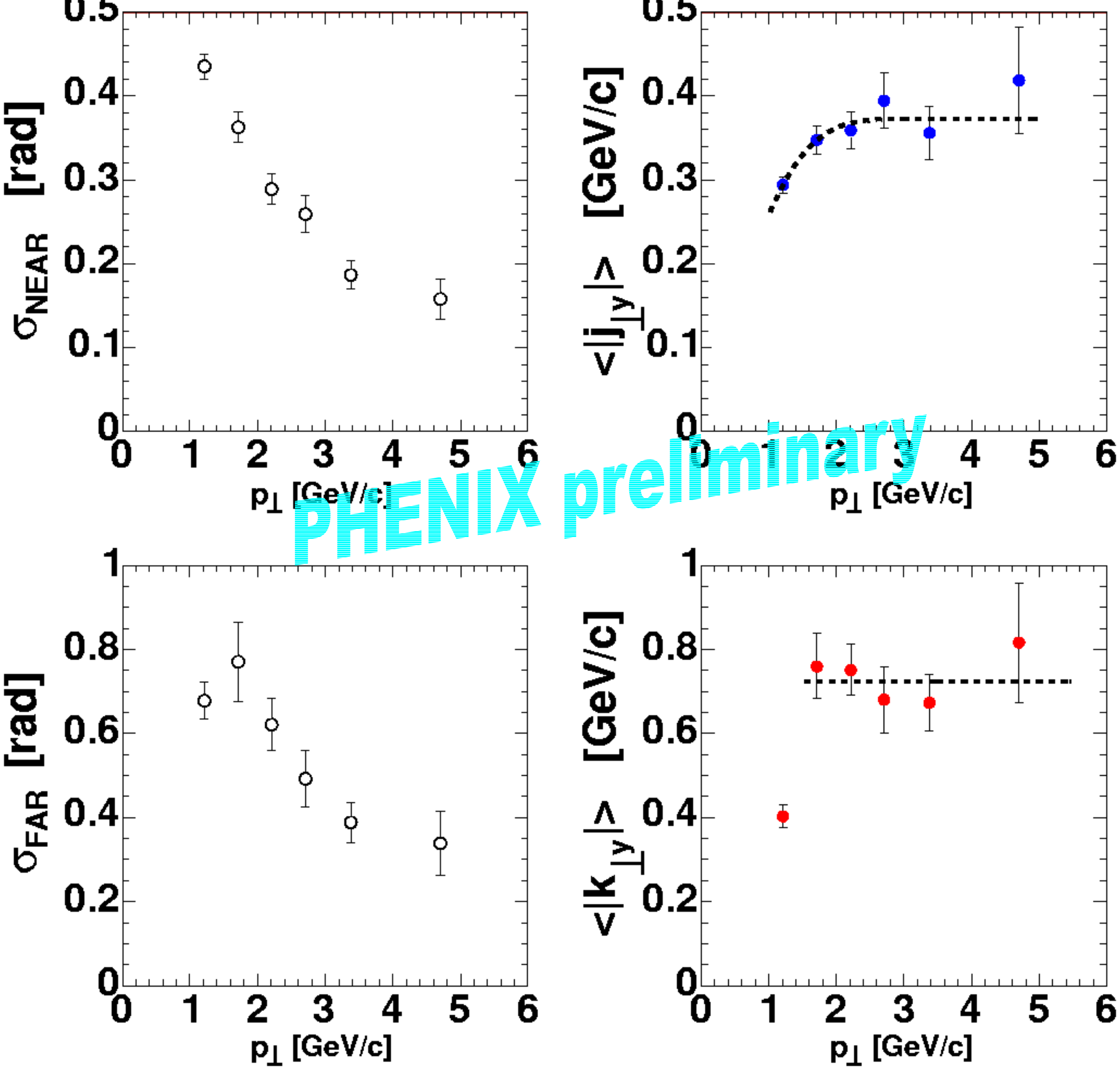
$\langle z\rangle$ - derived from high-$p_T$ inclusive $d\sigma/dp_T$

$\langle x_h\rangle$, $\langle p_T\rangle^2$ and $\sigma_F$ measured.

Taking into account the mean jet fragmentation transverse momentum $\langle|j_{Ty}|\rangle > 0$ makes the formula more complex, but the idea is the same. If you really want to see it, ask me in the discussion.

# charged hadrons correlation in pp $\sqrt{s}$ = 200GeV

No systematic errors shown




At low $p_T$<2GeV the near angle peak width and $\langle|j_{Ty}|\rangle$ is reduced by “Seagull effect”

see. e.g **Phys.Lett.B320:411-416,1994**

pp reference

PHENIX preliminary

$\langle|j_{Ty}|\rangle$ = 373±16 MeV/c

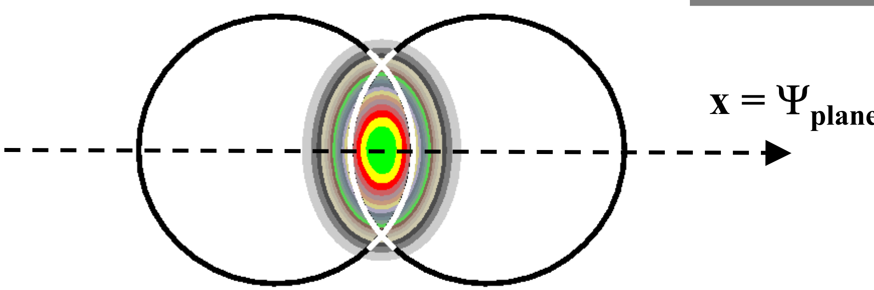
$\langle|k_{Ty}|\rangle \langle z\rangle$ = 725±34 MeV/c

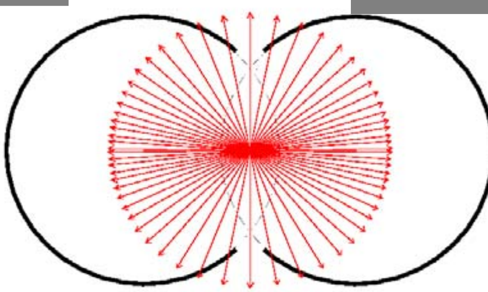
pol0 fit to data above 1.5 GeV/c

# In AA some algebra of v2+jets needed

In AuAu collisions the situation is more complicated by presence of “global” correlations induced by nuclear geometry - called elliptic flow.

multiple scattering → larger pressure gradient in plane → more particles emitted in plane



spatial asymmetry
eccentricity

$$\varepsilon = \frac{\langle y^2 - x^2 \rangle}{\langle y^2 + x^2 \rangle}$$

momentum asymmetry
elliptic flow - v2

$$v_2 = \frac{\langle p_x^2 - p_y^2 \rangle}{\langle p_x^2 + p_y^2 \rangle}$$

$$C(\Delta\varphi) = \frac{d^2N}{d\Delta\varphi} = \int_{-\pi}^{\pi} \frac{dN}{d\varphi}\frac{dN}{d(\varphi+\Delta\varphi)}d\varphi \qquad \frac{dN^{FLOW}}{d\varphi} \propto (1+2v_2\cos(2(\varphi-\Psi))) \oplus \frac{dN^{JET}}{d\varphi} \propto Gauss(\varphi,\sigma)$$

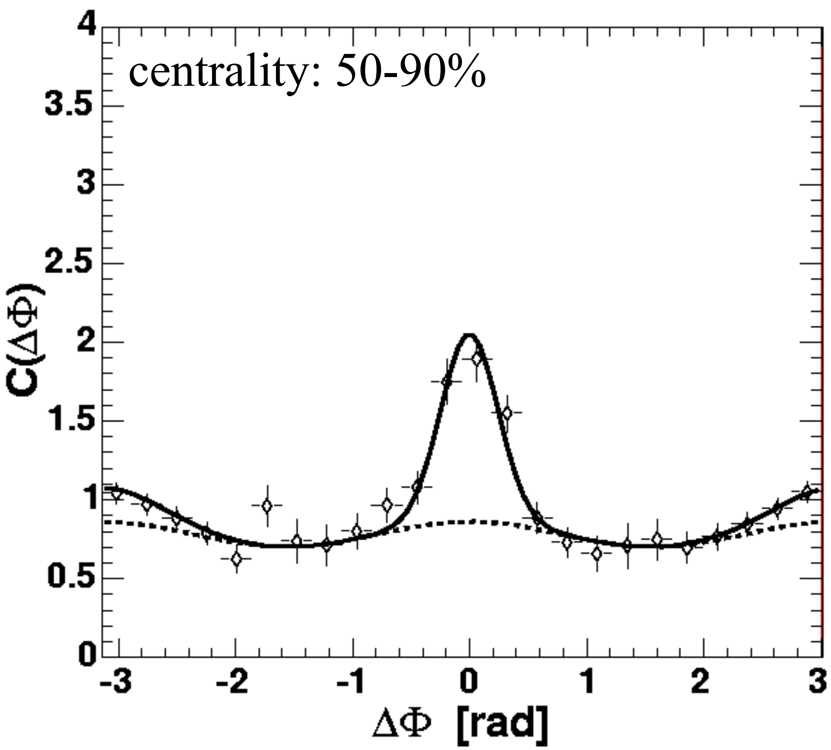
$$C(\Delta\varphi) \propto (1+2v^2{}_2\cos(2\Delta\varphi)) + Gauss(\Delta\varphi,\sqrt{2}\sigma) + Crossterm(\varphi_{jet}-\Psi)$$

Flat if no correlation between $\Psi_{plane}$ **and jet thrust**

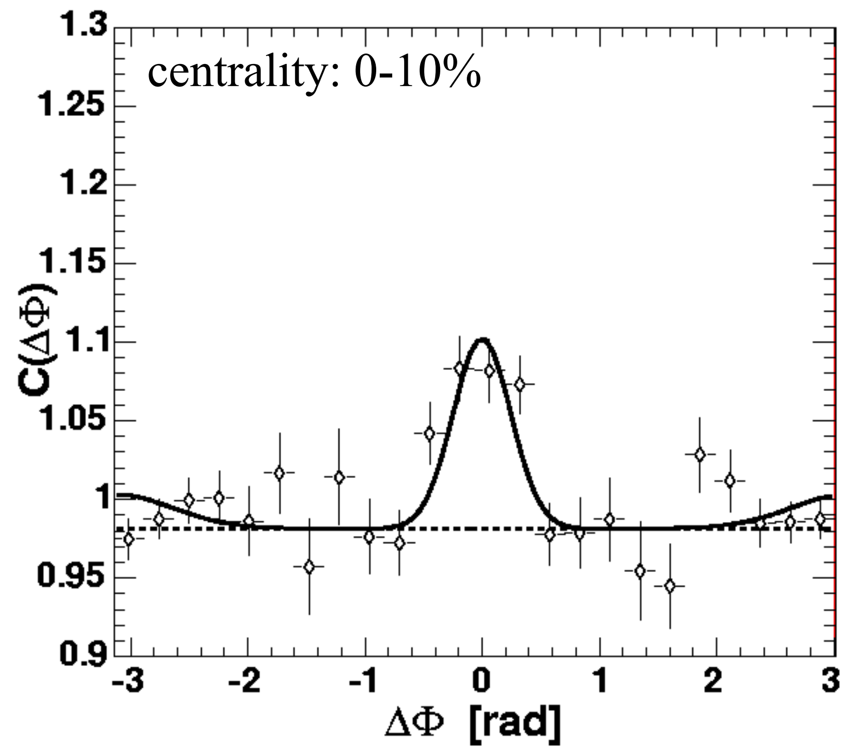
# AuAu charge hadrons correlation 2.2<pT<5.0 GeV/c

$$\text{Fit} \propto \overbrace{(1+2\,v_2^2\cos(2\Delta\varphi))}^{\text{AuAu}} + \text{const} \otimes \overbrace{[\text{Gauss}(\Delta\varphi=0,\sigma_N)+Y_F/Y_N\,\text{Gauss}(\Delta\varphi=\pm\pi,\sigma_F)]}^{\text{pp}} + \text{const}$$

$v_2^2$ determined from the fit $\sigma_N$, $\sigma_F$, $Y_F=\int \text{gauss}(0)\,/\,Y_N=\int \text{gauss}(\pm\pi)$ fixed values taken from pp




Flow and jet part can be clearly separated.

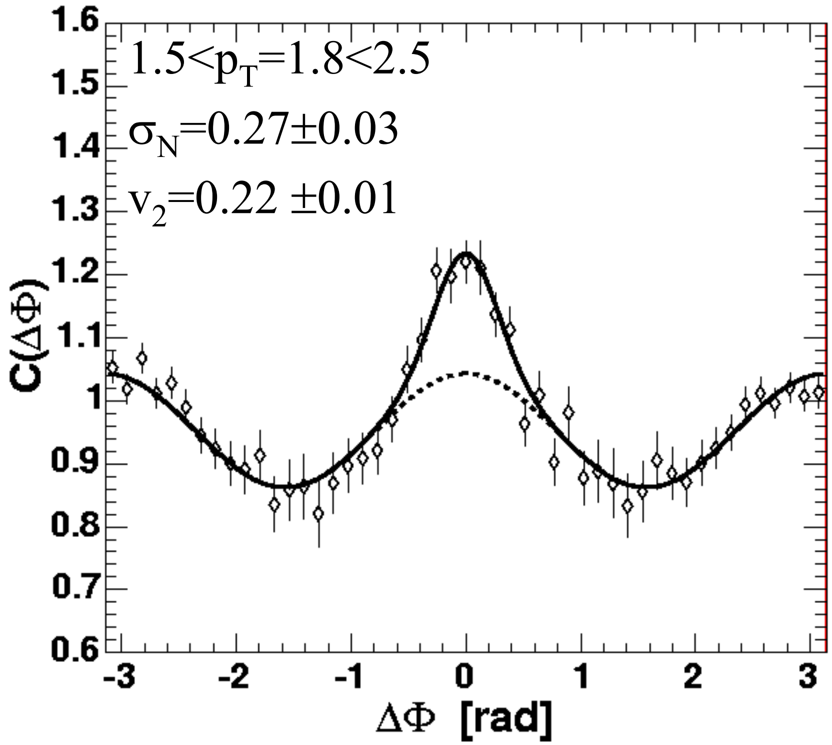



Fit forces $v_2 \to 0$, it indicates the lack of back-to-back correlation

# Far angle peak width in AuAu, v2-reduction

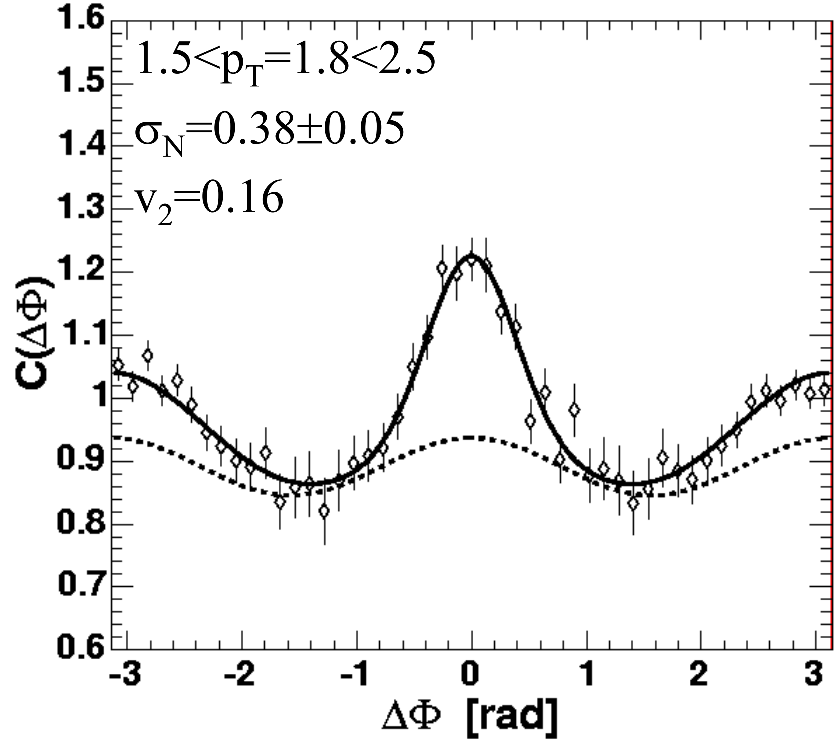
AuAu $\sqrt{s}$ = 200GeV centrality 50-90%

(this is only for illustration, not a physics result on $v_2$ or $\sigma_N$)




Fit $\propto$ $(1+2v^2{}_2\cos(2\Delta\varphi))$ + Gauss(0)

Omitting the back-to-back part leads to $v^2{}_2$ overestimation and consequent reduction of $\sigma_N$




Fit $\propto$ $(1+2v^2{}_2\cos(2\Delta\varphi))$ + Gauss(0)+Gauss($\pm\pi$)

Reduced $v^2{}_2$ is fixed

In this case the $\sigma_N$ has the same value as in pp and back-to-back part can be subtracted.

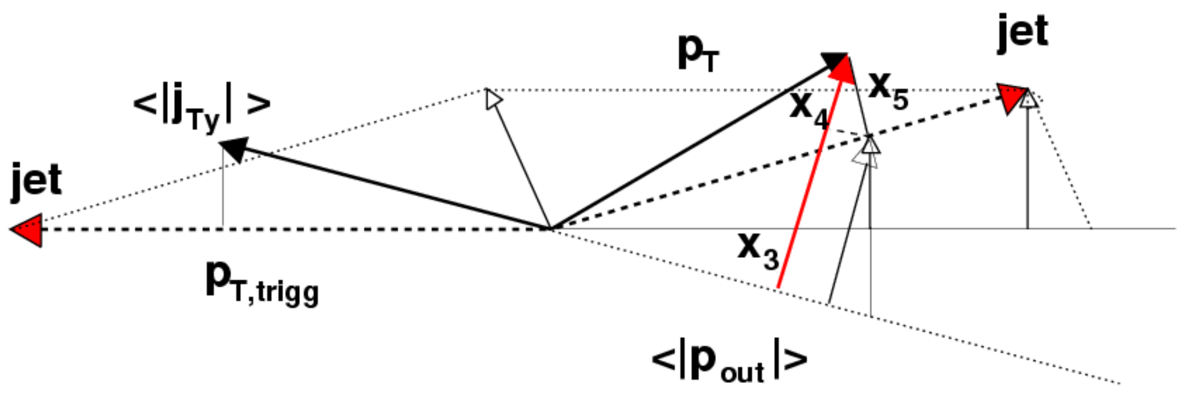
# Summary

- mean jet fragmentation transverse momentum $\langle|j_{Ty}|\rangle$ and the intrinsic partonic transverse momentum $\langle|k_{Ty}|\rangle$ were measure in pp collisions at $\sqrt{s_{NN}}$=200GeV.

- Jet-like structure also observed in AuAu correlation functions. The extraction of jet parameters complicated be presence of elliptic flow correlation pattern. Various techniques of simultaneous fitting are investigated.

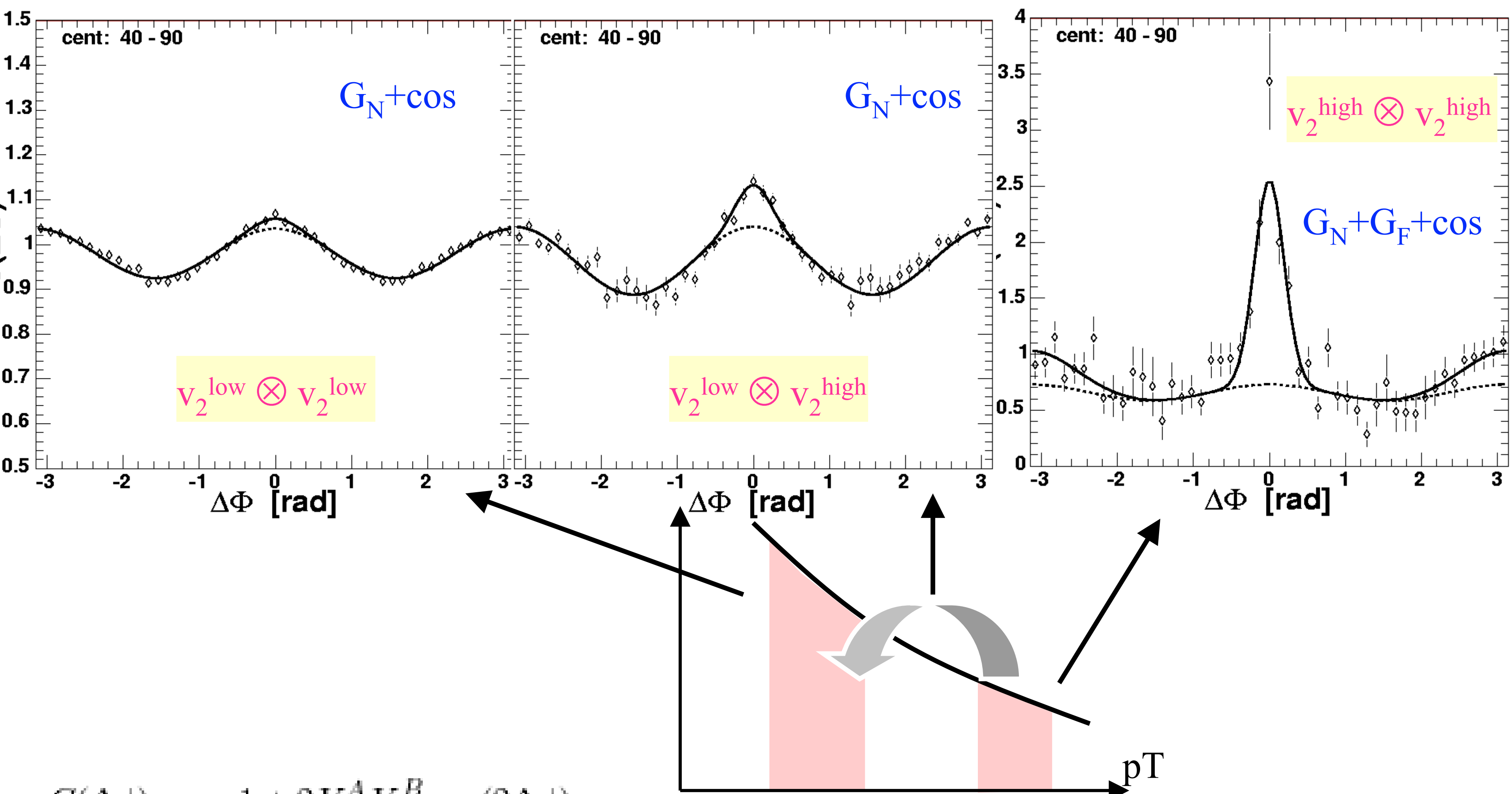
- Extraction of $\langle|j_{Ty}|\rangle$ , $\langle|k_{Ty}|\rangle$ and fragmentation function from d-Au and AuAu data is in progress.

# Complete formula




$$\sin^2 \left(\sqrt{\frac{2}{\pi}}\sigma_F\right) = \frac{x_h^2}{\langle p_\perp \rangle^2}\left[2\langle k_{\perp y}\rangle^2 \langle z \rangle^2_{trigg}\left(1 - \frac{\langle |j_{\perp,y}| \rangle^2}{\langle p_{\perp,Trigg}\rangle^2}\right) + \langle |j_{\perp,y}|\rangle^2 \cos \Delta\phi \right] +$$
$$+ \frac{\langle |j_{\perp,y}|\rangle^2}{\langle p_\perp \rangle^2}\left(1 - \frac{\langle k_{\perp y}\rangle^2 \langle z \rangle^2_{trigg}}{\langle p_{\perp,Trigg}\rangle^2}\right)$$

# Simultaneous fitting




$$C(\Delta\phi) = 1 + 2V_2^A V_2^B \cos(2\Delta\phi) + \frac{n^{AB}_{\mathrm{JetSameSide}}}{n^A n^B} J^A \circ J^B(\Delta\phi) + \frac{n^{AB}_{\mathrm{Di-Jet}}}{n^A n^B} J^A \circ J^B \circ E^{AB}(\Delta\phi - \pi)$$